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GROUND WATER AND DRAINAGE PROBLEMS OF THE WEBER BASIN PROJECT, UTAH

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IRRIGATION AND DRAINAGE
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GROUND WATER AND DRAINAGE PROBLEMS OF THE WEBER BASIN PROJECT, UTAH

F. M. Warnick,[1] A.M. ASCE, and William H. Greenhalgh

A great deal has been said about the Weber Basin Reclamation Project, but we would like to tell you about some of our special problems. However, to acquaint you with the general nature of the project, we will roughly outline it to you. This will be followed by an enumeration of the drainage and ground-water problems on the project and a statement of the objectives of the Bureau of Reclamation's investigational program. The remainder of our paper will be devoted to a treatment of the investigations, themselves. A paper might be prepared on any one of these subjects, but a general picture will no doubt interest many of you.

INTRODUCTION

The Weber Basin Project is located on the Weber River and tributaries in Weber, Davis, Morgan, Box Elder and Summit counties.

By means of three newly constructed reservoirs, two enlarged reservoirs, wells, drains, and conveyance facilities, the Weber Basin Project will develop for multiple purposes practically all of the presently unused surface and ground-water supplies of the Weber Basin. The water will be regulated and distributed to meet the immediate and future needs of agriculture, municipalities and industries. Hydroelectric power will be generated to the limited extent possible with presently feasible potentialities. Flood damage from the Weber and Ogden Rivers will be practically eliminated. Seeped lands will be drained and mosquito-breeding areas eliminated. As far as practicable, damage to fish and wildlife will be prevented and conditions for game improved. Recreational opportunities will be provided.

Full project development will provide an average of 270,100 acre-feet of water annually, including 164,600 acre-feet for irrigation, 40,000 acre-feet for municipal and industrial use, and 65,500 acre-feet that will appear below reclaimable lands and be used for migratory waterfowl refuges.

Drainage is of prime importance in the Weber Basin Project since the feasibility of the project depends to a large extent upon the successful drainage and reclamation of lands that are now undeveloped or have been abandoned because of a high water table.

Drainage Problems

Drainage was not a problem for the early settlers of the Weber Basin. Irrigation was first practiced on lands near existing stream channels and adjacent to the shore of Great Salt Lake. Good yields were obtained and the

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lands were extensively developed. As irrigation expanded to higher lands, drainage problems developed in the lower areas and eventually large areas were abandoned. Many private drains were constructed but these generally were limited to small tracts of land and were successful only in areas where natural drains or breaks in the topography were of sufficient depth to dispose of the drainage water. Many drainage attempts failed on the larger, flatter areas because outlet channels could not be provided by individuals or small groups of landowners.

Recent detailed land classification and drainage investigations have shown definitely that there are 49,000 acres of land in the Weber Basin Project that now require drainage relief and for which drainage is economically feasible. These lands consist of 29,500 acres of land that have impaired productivity and 19,500 acres of land that are presently nonproductive or provide only low-grade pasturage. They can be made fully productive by drainage and reclamation.

Drainage problems as they relate to their successful solution for lands needing drainage relief in the Weber Basin are quite varied and complex. The principal causes of drainage deficiencies on project lands are application of water without due regard for beneficial irrigation practices, water caused by artesian pressure, inflow of ground water to low-lying lands from irrigation losses on bench lands, inadequate disposal of natural runoff, leakage from canals and laterals, and flow from artesian wells improperly capped or controlled. A coordinated system of interceptor, collector and lateral drains, artesian or pump wells, lining of canals, capping unused flowing wells, and education of irrigators in better irrigation practices will be required to completely alleviate the waterlogged condition of the project lands.

Ground-Water Problems

The ground-water investigations are an attempt to formulate plans for providing effective drainage relief for project lands located in areas having upward flow from artesian aquifers and if practical to develop water for project purposes. The heterogeneous nature of the soils coupled with the complicated ground-water conditions that exist necessitates extensive studies in order to obtain the information required for solution of the drainage problems and possible development of the ground-water resources of the area.

The principal factors which singly or in combination complicate development of the ground-water resources are where does the ground water come from, can recharge be increased, can upward leakage from the artesian aquifers be controlled, will quality of water limit its use, can leakage from old wells be eliminated, can present uses be modified to increase the yield of the basin and can legal barriers be overcome?

Geologic Formations and Their Relation to Drainage and Ground Water

Geologic formations divide naturally into two classes with relation to occurrence of ground water in the area. On the one hand are the pre-Cambrian and Paleozoic "hard rocks" of the Wasatch Mountains; on the other, the weakly consolidated and unconsolidated formations that underlie the valley.

Investigations to date show that the rocks of the Wasatch Mountains, even including the metamorphic pre-Cambrian sequence are so thoroughly fissured by faults and joints that they accept large quantities of water originating as

precipitation or as snow melt, store and transmit the water, finally to discharge it as springs and seeps above ground, as increments to surface streams, or as hidden discharge to subsurface aquifers along the contact between the rocks of the mountains and the valley fill.

The principal ground-water reservoirs of the area occur, of course, in the sedimentary materials underlying the valley. Textures range from very fine sticky clay to boulders incorporated in torrential stream deposits and in mud flows. Aquifers developed to date in the area are thought to be restricted in the main to the sequence of strata laid down by Lake Bonneville and to a little-known sequence immediately underlying the Bonneville group.

Aquifers of larger yields occur in coarse sands and gravels deposited as sheets, fans, or aprons off the mouths of the principal canyons of the range. In most of the area, some at least of the aquifers are enclosed by strata of appreciably lower permeability. Artesian rise, therefore, is commonplace, and flowing wells are obtained by drilling in many places.

So far as is known, no bedded salt deposits occur in the area, and the sediments yield water of fair to excellent quality. Saline waters have been encountered in about 10 percent of the area but are not known to originate by solution of salts from the aquifers. It is more likely that the salts are introduced by waters rising along buried fault zones, probably those related to Utah Hot Springs and El Monte Springs.

Objectives of Weber Basin Studies

The objectives of the drainage and ground-water investigations are as follows:

(1) To secure information from which a plan may be formulated for a drainage system that will reduce the effects of upward leakage from artesian aquifers, will lower the water table on project lands to where sustained agricultural production may be maintained, will guard project lands against "waterlogging" due to irrigation, will protect non-project lands that might be affected by seepage from irrigated project lands and provide the necessary data for the design and construction of such a system.

(2) To determine to what extent drainage flows, water from artesian relief wells and additional ground-water development can be used for project purposes. Use of these potential supplies would increase the water supply to the project and permit increased agricultural and industrial development of the area. Utah has much more land suitable for development than it has supplies of surface water for irrigation. Development of significant quantities of underground water would, by interconnections and exchanges with projects both North and South of the Weber Basin Project, permit the utilization of a portion of this very productive but now barren land. The results of this study will therefore have an important effect on the development of not only the Weber Basin area but of other parts of the state.

Drainage Investigations

Investigations of the unconfined ground-water surface, or water table, began in 1948. Since that time approximately 480 2"x10' perforated downspout casings and 780 $\frac{3}{8}$-inch piezometer wells have been installed to study water-table conditions and artesian leakage problems.

Depth-to-water maps compiled from observation well records have been prepared for high and low ground-water stages on progressively greater

project coverage through 1949 to July 1954. These show clearly the area requiring drainage relief and protection. They also show the effects of existing drains and natural outlets. Areas waterlogged as the result of artesian leakage are also defined.

Water-stage recorders have been installed on 12 2"x10' unconfined ground-water wells located in the East Shore Area between Bountiful and Plain City. Records obtained show the continuous fluctuations of the water table. The wells are situated in cultivated areas removed from the influence of ditch or canal lines. Over one year's record has been obtained for six of these wells while records of two or three months have been obtained for the remainder.

Weekly hydrographs obtained from the unconfined ground-water recorder wells show the daily effects of evapo-transpiration losses and recharge from leaky artesian aquifers. Irrigation water applications are sharply defined as is the drainability or permeability of the soil as the water table drops. Additions to the water table from precipitation are also shown. These records are extremely useful in evapo-transpiration studies and will be used in the permeability determinations for drainage design. They may also be a useful tool to encourage improved irrigation practices.

The extent and degree of the artesian pressure causing upward flow of artesian water into the upper 10 feet of the soil profile has been investigated by means of piezometer wells installed in clusters of from 2 to 4 wells, ranging from 8 to 30 feet in depth. Approximately 210 such clusters have been installed to delineate areas of artesian leakage. These clusters are read semi-annually. Approximately ninety $\frac{3}{8}$-inch wells ranging in depth from 30 to 300 feet have been installed to investigate the shallow artesian aquifers.

During the spring of 1952, stream-gaging stations were established on six major outflow channels leading from the East Shore Area. Their purpose is to obtain volumetric outflow data for use in studies of the feasibility of re-using these flows for irrigation or other beneficial uses within the project boundary. Chemical analyses indicate the quality of these flows to be suitable for irrigation use.

Subsurface exploration has been carried on concurrently with the ground-water investigations. The profile of each piezometer well was logged at the time the well was installed. Approximately 1450 well and soil profile logs ranging in depth from 8 to 300 feet have been made in the East Shore Area. The majority of these soil logs are from 10 to 20 feet in depth.

These soil logs were made for the purpose of locating clay barriers, sand and gravel lenses, and hardpan layers to assist in determining the location, depth and spacing of proposed drains. The logs are also used to locate shallow artesian aquifers contributing to the waterlogged condition of the land.

The Bureau of Reclamation is taking advantage of private drainage construction in order to obtain valuable information relative to the effectiveness of drains as well as soil conditions and problems encountered during the construction period. The results of the observation wells installed in the vicinity of these drains are very encouraging and are providing a source of valuable information.

Drainage investigations have progressed to a point where actual operating data are required before the project drainage system can be designed. To provide some of the data required, a contract for construction of the Hooper Pilot Drain was awarded last spring and construction was recently completed. Other pilot drains are scheduled for construction during 1955. Some interesting information on this drain will be given by A. Alvin Bishop in his paper.

As other drains are constructed, additional observation wells will be made

to determine the effectiveness of the drainage program. These studies will provide data necessary for final selection of the drainage system.

Ground-Water Investigations

The cost of extensive deep subsurface exploration to determine the physical characteristics and location of the ground-water aquifers would be prohibitive.

We have secured from the Utah State Engineer's office the logs of approximately 1200 wells that are located within the project boundary. In some of the areas within the project boundary there is a scarcity of such information. This situation is being remedied by jetting small diameter wells to obtain the desired logs.

Through the use of these well logs, together with ground-surface elevations, profiles and cross sections are being produced to provide a pictorial representation of the subsurface conditions. Information derived from these sources is of importance in determining the continuity, depth and thickness of aquifers, uniformity of formations, probable areas of recharge and artesian leakage and definition of the limits of perched water tables. This information will also be helpful in determining locations and depth of wells which may be used for the dual purpose of drainage relief and supplemental water supply.

An inventory of the wells of the East Shore Area from Salt Lake City to Perry has been completed. This inventory provides a record of the discharge, pressure, diameter and other pertinent data under pre-project conditions of about 3000 wells and will be valuable as a historical record. The inventory shows that about 50,000 A.F. annually is being withdrawn from the basin.

The observation of water levels and artesian pressures in existing wells was initiated by Bureau personnel in 1952. Prior to this time the Geological Survey had made periodic observations on 16 wells within the project area since 1936. These wells together with approximately 150 other wells were incorporated into a monthly observation program in order to obtain data for use in the ground-water investigations. Approximately 15 wells are included in weekly observation programs; and continuous recorders, either float operated or pressure operated, are maintained on 11 of the 15 wells.

Piezometric surface maps have been prepared using the artesian pressure data. These maps show the magnitude and distribution of pressure in the deep confined aquifers and provide good evidence as to the location of the recharge areas. These maps will be correlated with quality of water, temperature and geologic data through the use of overlays. It is expected that such correlation will yield further evidence on recharge and new evidence on the origin and occurrence of mineralized water. The maps will also help to define fault barriers and the movement of ground water in general.

Upward leakage from underlying artesian basins is contributing to the waterlogging of a large portion of the East Shore Area. Twenty-eight deep piezometers have been installed to obtain data on the pressure differential through the leaky cap or confining strata. These deep piezometers generally range in depth from 80 to 300 feet as compared to the shallow piezometer clusters ranging in depth from 8 to 30 feet.

Pumping, constant-head discharge (Jacob-Lohman) and recovery tests are the only practical methods of determining the hydraulic characteristics of an aquifer. The pumping tests thus far made have been in aquifers of high transmissivity and have illustrated an abundance of ground water available in various parts of the project.

In the summer of 1953 a study of the quality of the ground water, or more specifically a study of the chemical make-up of the dissolved solids in the water, was initiated. Over 100 water samples have been collected and analyzed to date. They have been collected from streams, wells, drains, seeps, springs (including hot springs), and from the water intercepted by the Gateway Tunnel.

These studies have several purposes. One is to study the source and direction of flow of the ground water including the origin, occurrence and potential spread of mineralized water. A second is to provide information on the suitability of the ground water for irrigation and upon the availability of suitable water from some areas. A third is to provide a historic record of the chemical quality of individual wells and from various areas in the project that will be useful throughout the entire development and operation of the project.

Thus far these studies have shown that water of a quality suitable for irrigation can be produced from most of the aquifers.

The recharge studies are being made to determine the source or origin of the waters of the East Shore aquifers and to determine the quantity of annual recharge to these aquifers. Both purposes point to determination of the amount of ground water that can be developed as part of the project water supply and the amount that can artificially be added to the annual recharge occurring naturally.

Geologic mapping has revealed that much of the foothill regions is underlain by silts and clays which would inhibit percolation of water to the aquifers below.

Seepage-loss studies in lower Weber Canyon show that the river loses 4 percent to 5 percent of total flow depending upon the quantity of the flow within the $1\frac{1}{2}$-mile reach just below the mouth of Weber Canyon. Below this $1\frac{1}{2}$-mile reach the river appears to be in equilibrium.

It now appears that most of the recharge from surface waters occurs at the mouth of Weber Canyon with smaller amounts occurring at Bountiful, Farmington and North Ogden. It also seems apparent that an unknown but presumably large amount of recharge occurs by subterranean flow through the base rock of the mountains.

Recharge experiments have been run in the recharge area at the mouth of Weber Canyon. The first experiment was run for a period of one week and the second experiment for about six weeks. These experiments have shown that the Weber River recharge area has a high infiltration rate and indicate that artificial recharge is feasible. The amount of water dissipated in the recharge pit having a maximum surface area of 3.25 acres, during the 7-week test period, totaled 2,172 acre-feet. This amounts to an average continuous intake of approximately 7 c.f.s. per acre for the entire period of the experiment. The intake actually fluctuated between 5 and 9 c.f.s. per acre, usually increasing from a lower to a higher rate as the experiment went on. This recharge also had a very pronounced effect on the water levels in Observation Well No. 1 which is located approximately one-fourth mile west of the recharge pit. The overall rise in the water level amounted to 34.3 feet, reaching a high point on March 26, 1953, and being 141.3 feet below the ground surface at that time.

It is now evident that direct measurement of the annual recharge is physically impossible. Studies were initiated in February 1954 to measure recharge indirectly based on the premise that the total inflow into the East Shore Area, consisting of surface flow, subsurface flow or recharge, and precipitation, equals the total discharge out of the area, consisting of surface flow, springs

or seeps discharging directly into the lake, and evapo-transpiration losses, plus or minus changes in ground-water storage. In the above equation the subsurface flow or recharge is the unknown. The remaining quantities can be estimated to varying degrees of accuracy.

SUMMARY

By way of summary, the drainage investigations, in progress since 1948, are well advanced in all phases except the drainage performance studies. Considerable data have been collected on all but this latter item. A large part of the drainage investigation effort is being shifted to performance studies with a corresponding reduction of effort on other phases. The Hooper Pilot Drain has been constructed and extensive studies of its performance will be made. The construction of two or three additional pilot drains are planned in the next two years. The final design of the drainage facilities including artesian-relief wells must wait until the drainage-performance studies and the ground-water investigations are completed.

The ground-water investigations have been in progress for a year. While no conclusions can be safely drawn at this stage of the investigations, the information thus far gained indicates that the development of a large quantity of water from the East Shore aquifers will be feasible. Most of the East Shore aquifers and, in particular, those that have been tested thus far are highly productive. The annual yield does not appear to be limited by transmissivity of the aquifers but rather by annual recharge. The annual recharge appears to be ample and it can be increased by artificial means. On the other side of the ledger, the legal aspects present a presently indeterminate phase that could adversely affect the feasibility of the ground-water development. The effect of the mineralized aquifers has not been evaluated as yet although no insurmountable problems are anticipated.

The construction of two or three production wells and four or five pressure-relief wells are planned in the very near future.

PROCEEDINGS-SEPARATES

The technical papers published in the past year are presented below. Technical-division sponsorship is indicated by an abbreviation at the end of each Separate Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways (WW) divisions. For titles and order coupons, refer to the appropriate issue of "Civil Engineering" or write for a cumulative price list.

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c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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